NA49/NA61 vs FLUKA

Update for NUMIX meeting

Pedro Mediano

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NA49

Quick reminder

Beam: Protons with 158 GeV momentum

Target: Graphite for the **pion** production analysis and hydrogen for **kaon** analysis.

FLUKA: Version 2011.2b.4.

We're measuring invariant cross section binned in CMS Feynman X and transverse momentum (x_F, p_T).

$$f(x_F, p_T) = E(x_F, p_T)\frac{d^3\sigma}{dp^3}$$

NA49

$\pi^{\pm}$ phase space coverage

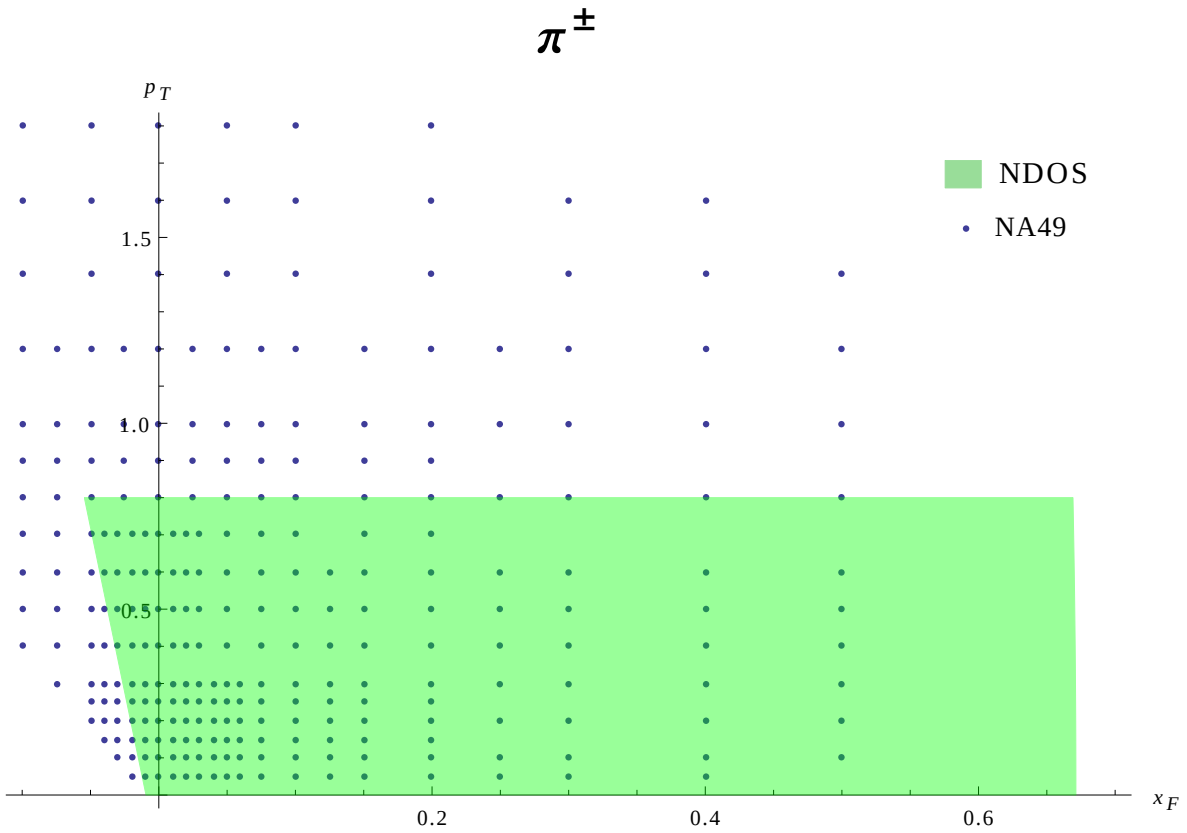


Figure: NA49 bin centers (points) and NDOS-relevant region (green)

NA49
$K^{\pm}$ phase space coverage

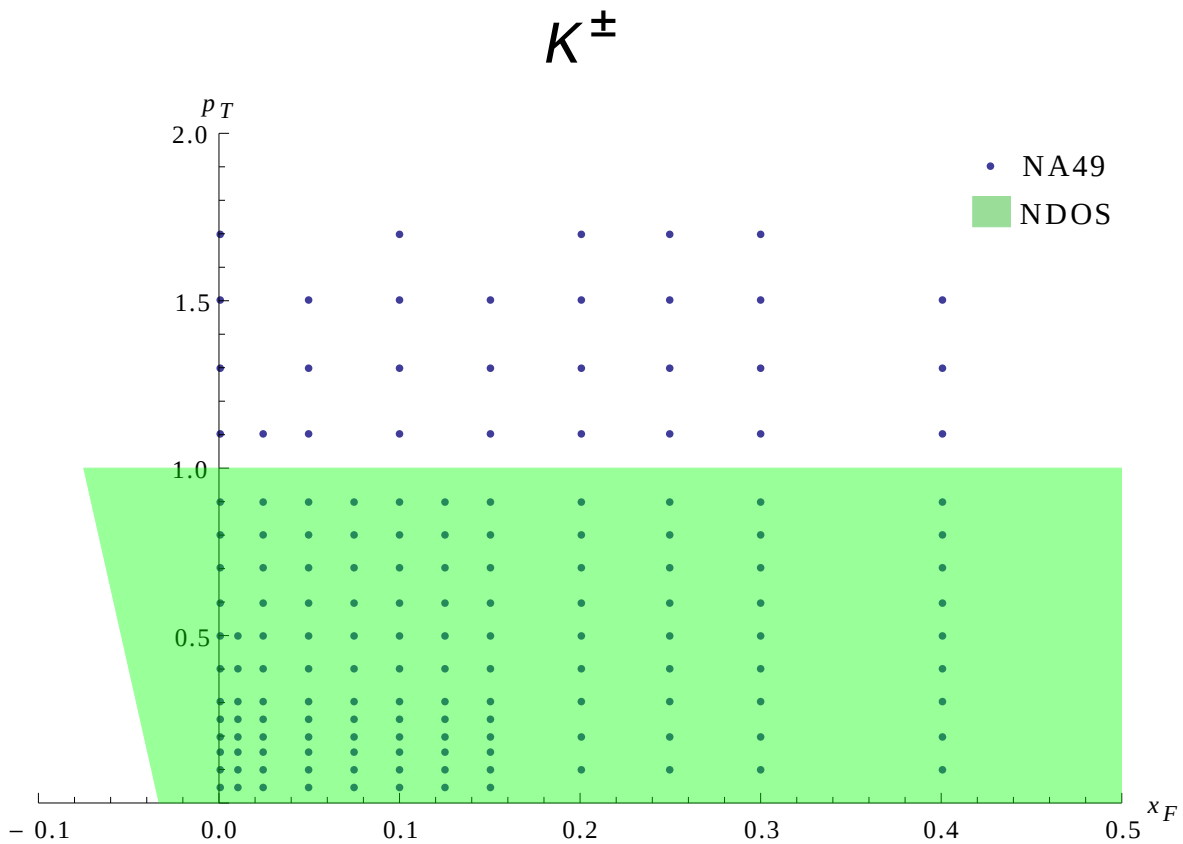


Figure: NA49 bin centers (points) and NDOS-relevant region (green)

General procedure

- Run FLUKA simulation. For this presentation, 25×10^9 POT in each case.
  - 500 statistically independent runs of 5×10^7 POT each.
  - **Note:** Error is computed as the variance of these 500 estimators.
- Gather the results and compute errors using pyROOT.
- Read NA49/NA61 data and compare to FLUKA using pyROOT. Build desired plots/histograms.

Some details

USRYIELD

- It can calculate invariant cross section in (x_F, p_T). By default uses the nucleon-nucleon CMS and gives the result in mb/GeV^2 (same as NA49).
- Scores particles as they emerge from the collision. Thus we avoid issues with reinteraction and decays.

Binning

- NA49 includes finite bin size correction factor.
- On our side, we can pick thin bins (0.005 wide in both x_F and p_T) so that correction is negligible.
- Bin centers of simulation exactly match bin centers in NA49.

Some details

Normalization

- With other estimators one must multiply each value by the width of the bin to get an integrated result. As far as I know this is **not** true for invariant cross section. Thus no factor is applied for this.
- We scale all results by the interaction probability.

Physics

- One run with FLUKA default PEANUT setting (using PEANUT for energy $< 5\,\mathrm{GeV}$).
- Another run forcing PEANUT for all interactions.

Some details

Comparison

- Standardized differences:

$$z = \frac{f_{FLUKA} - f_{NA}}{\sqrt{\sigma^2_{FLUKA} + \sigma^2_{NA}}}$$

- Relative differences:

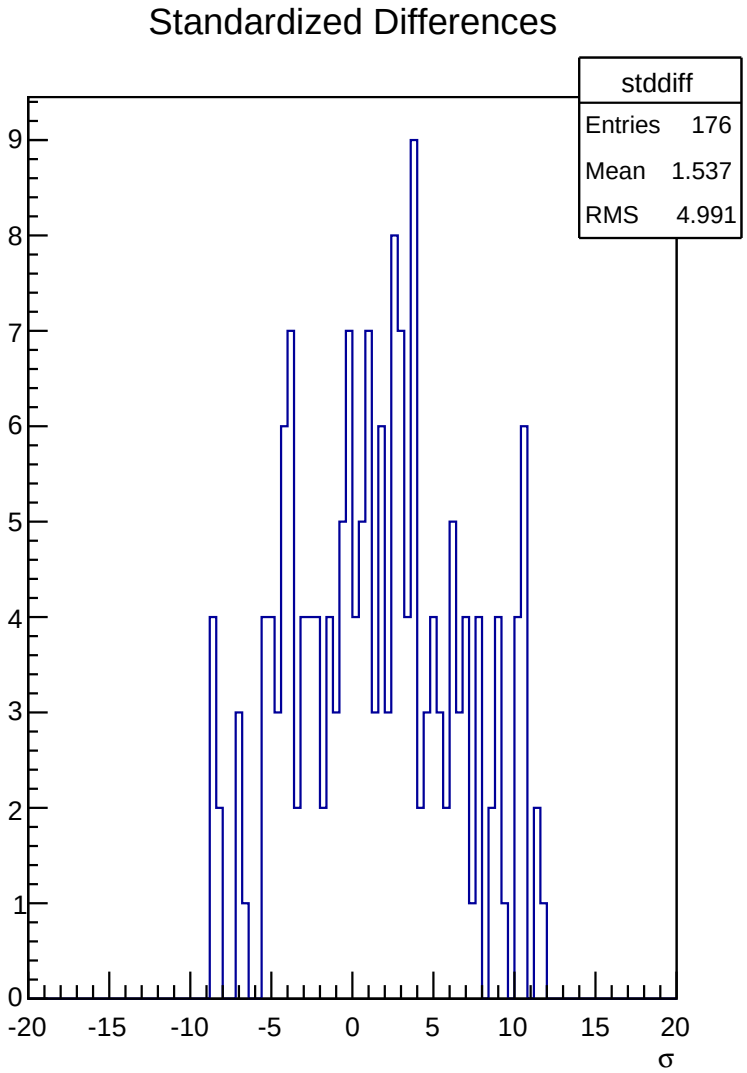
$$z = 100 \frac{f_{FLUKA} - f_{NA}}{f_{NA}}$$

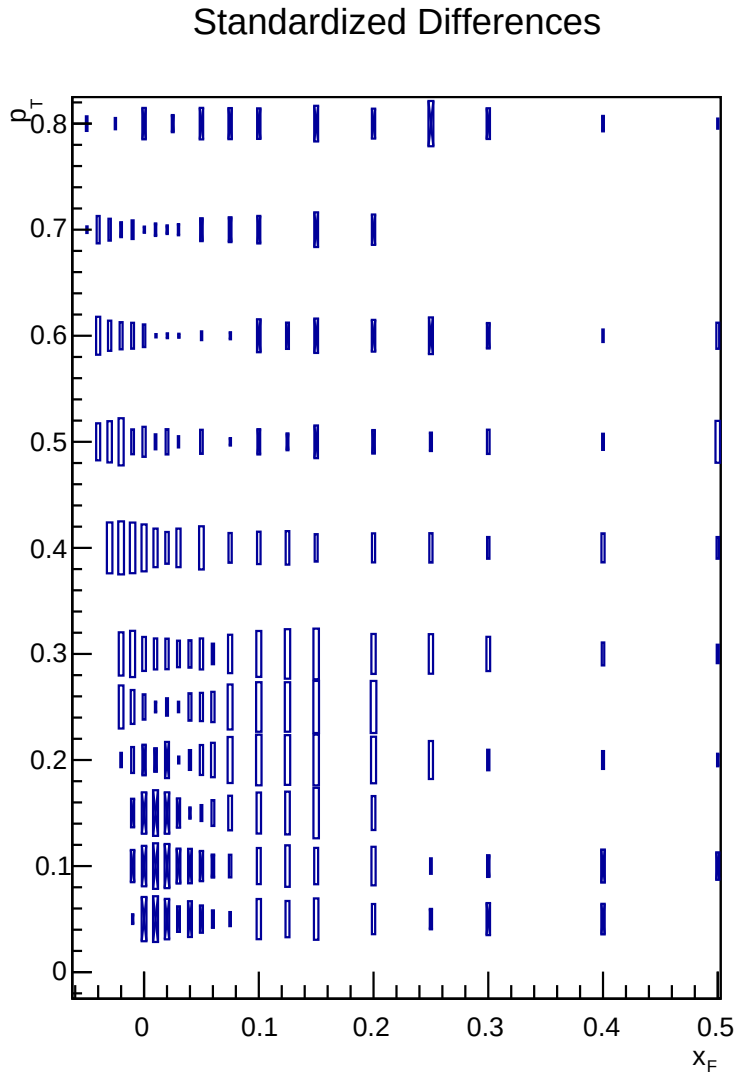
Uncertainty

We have simulated enough events to get a significantly smaller error than NA49.

Particle	MC mean error (%)	NA49 mean error (%)
π^+	0.5	3
π^-	0.6	3
K^+	1.8	3.7
K^-	2.2	4.2

NA49 π^+ Standardized Differences (as an example)

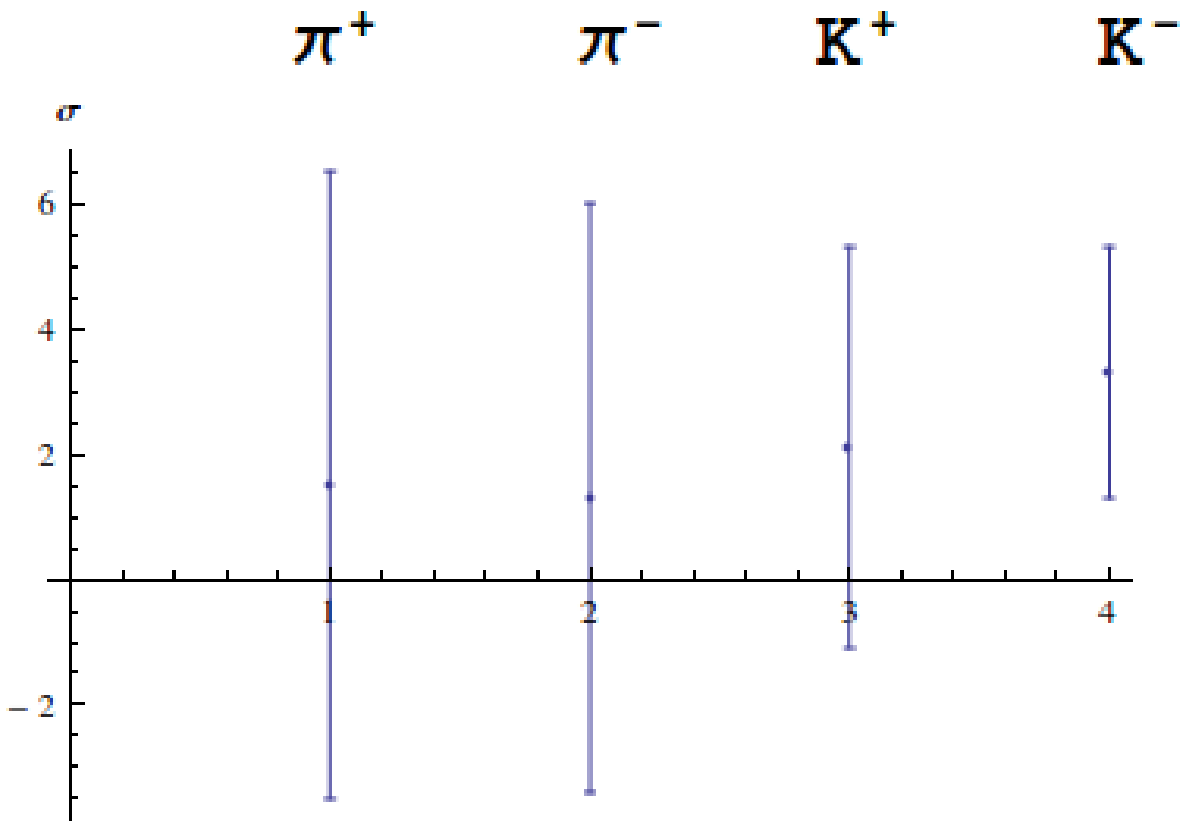




NA49 summary

Fluka (w/ PEANUT) - NA49

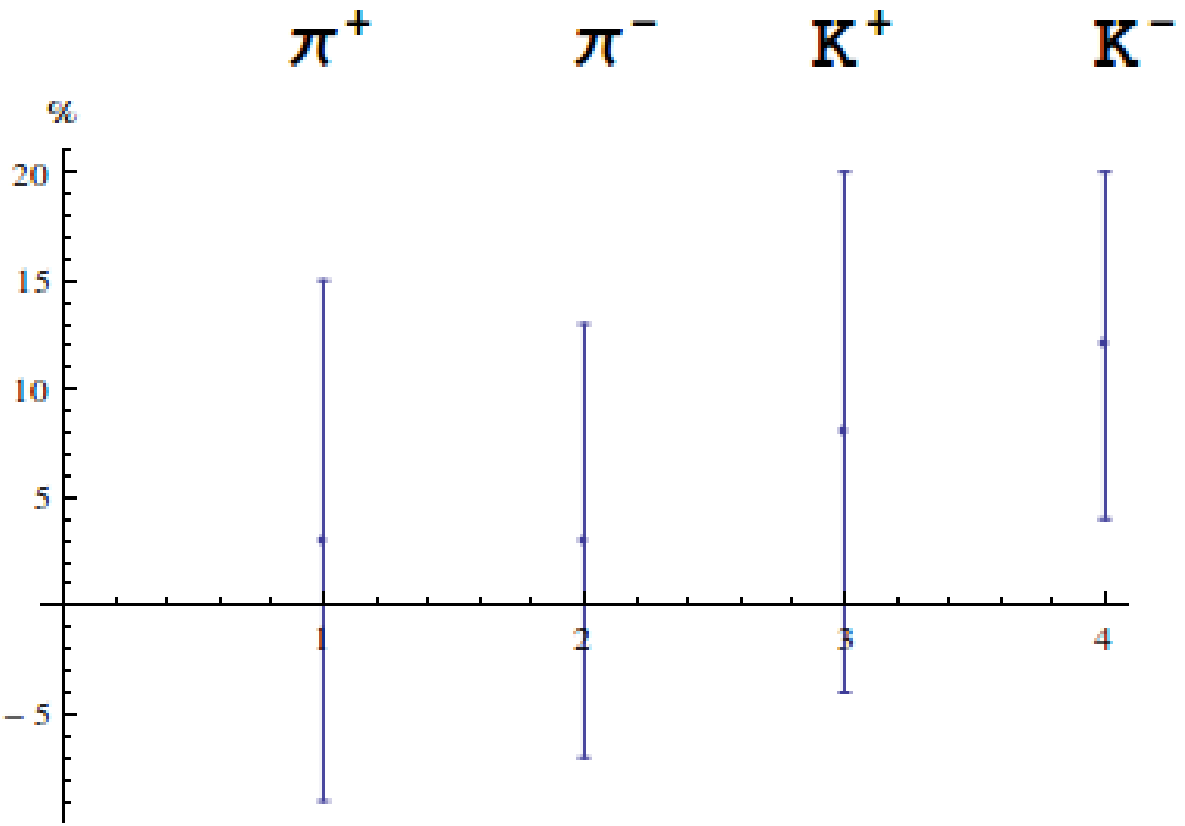
- Standardized differences



NA49 summary

Fluka (w/ PEANUT) - NA49

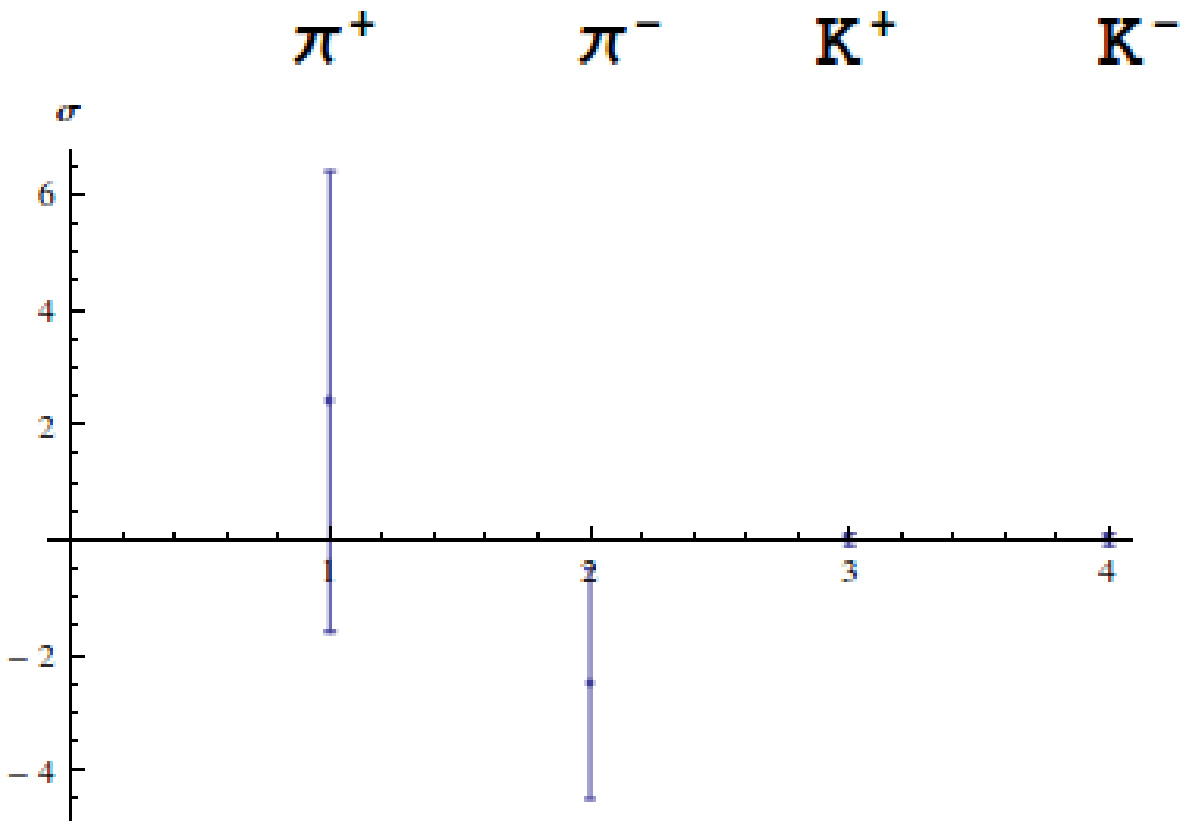
- Relative differences



NA49 summary

Fluka (w/ PEANUT) - Fluka (w/o PEANUT)

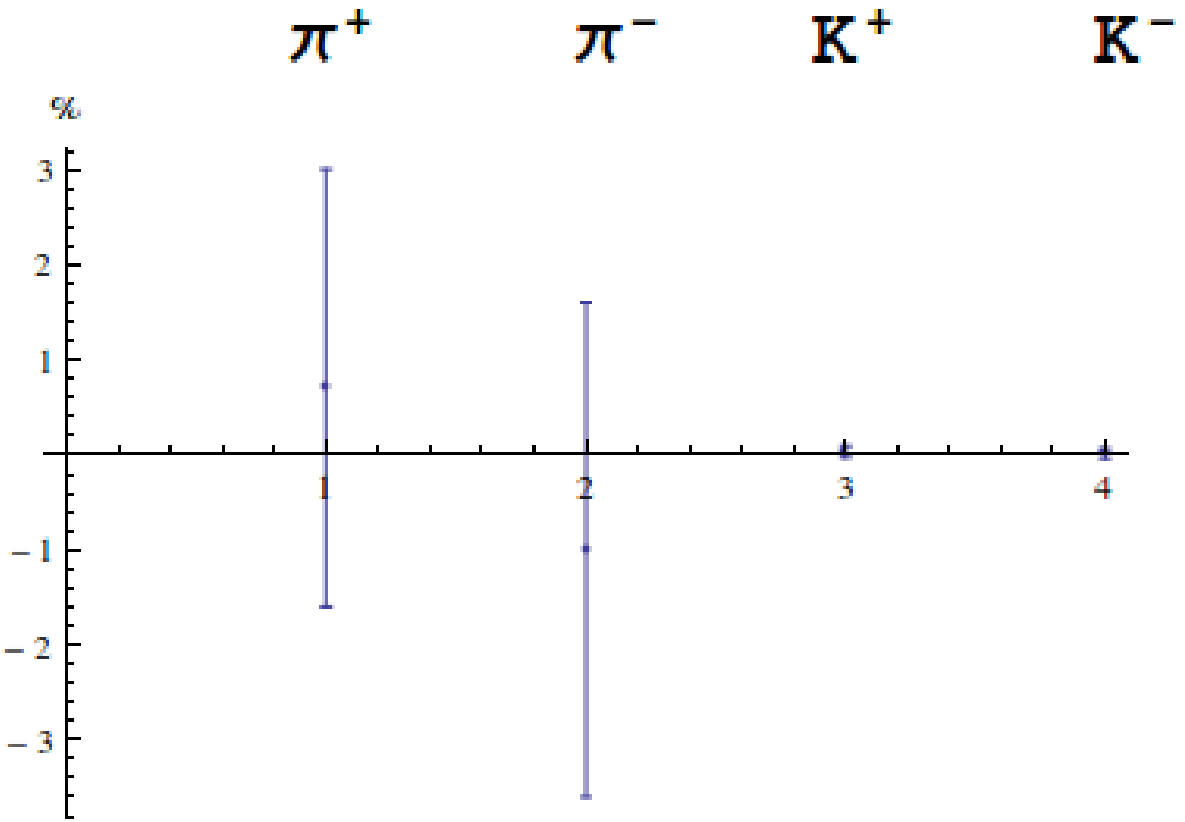
- Standardized differences



NA49 summary

Fluka (w/ PEANUT) - Fluka (w/o PEANUT)

- Relative differences



NA61

Changes w.r.t. NA49

Beam: Still protons, now with 31GeV momentum instead of 158 GeV.

Target: Only carbon.

Now we measure differential cross-section binned in total momentum and polar angle, both in LAB frame.

$$f(p,\theta) = \frac{d\sigma}{dp}$$

NA61

$\pi^{\pm}$ phase space coverage

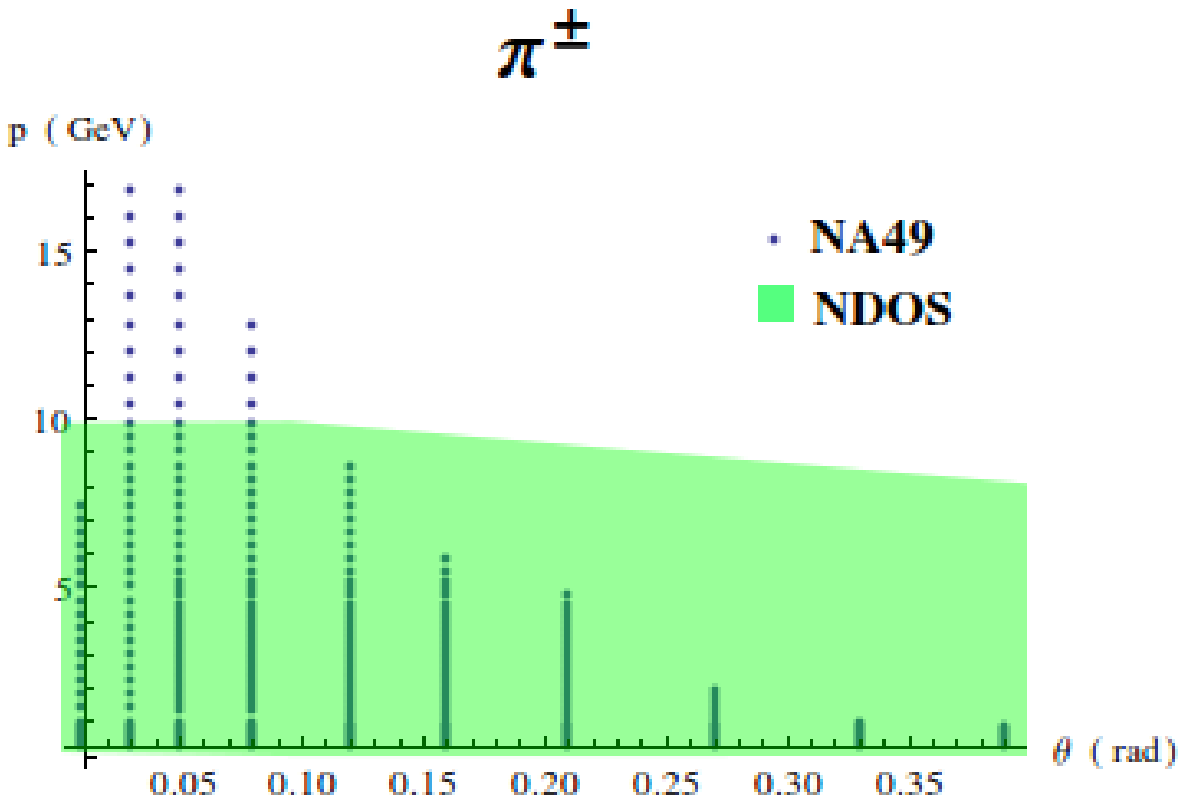


Figure: NA61 bin centers (points) and NDOS-relevant region (green)

Some details

USRYIELD The function can also calculate differential cross section in (p, θ). No problem here.

Binning

- NA61 do **not** include finite bin size correction factor.
- Thus, we match exactly the bin widths in NA61.

Some details

Normalization

- In this case we must multiply by the width of the angular bin in solid angle.
- Same issue as in NA49 with the scaling by the reinteraction probability.

Physics This time we only compare results from NA61 with FLUKA with forced PEANUT.

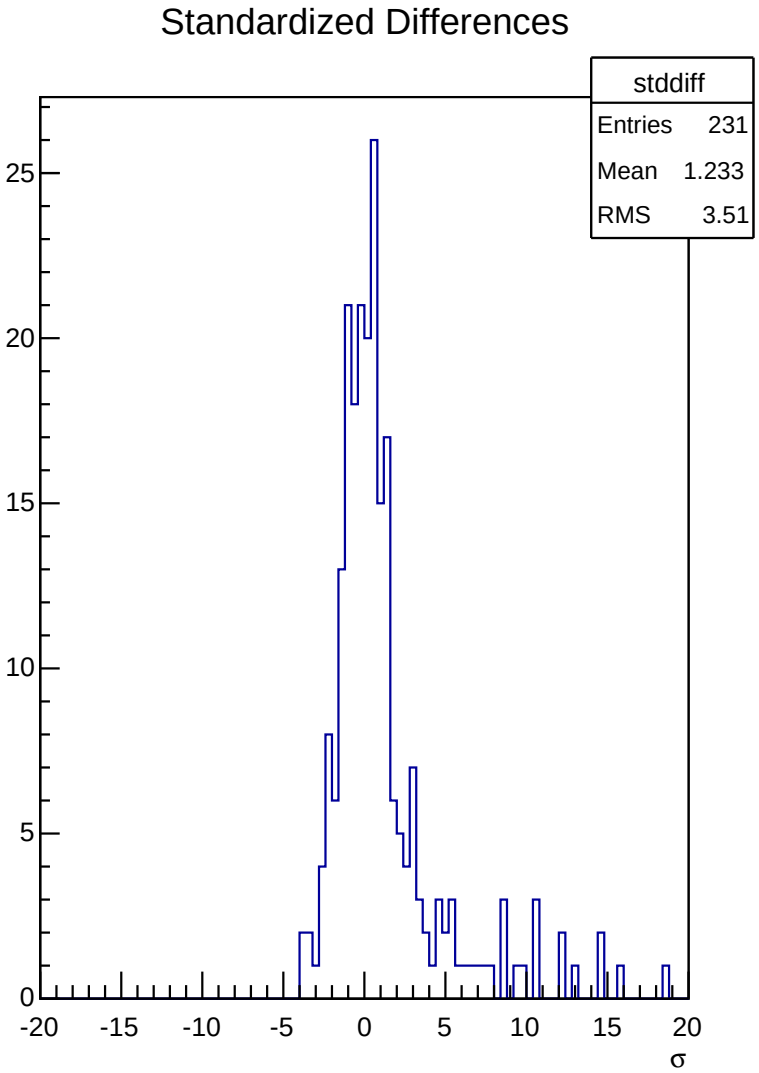
Comparison We use both standardized and percent differences, same as NA49.

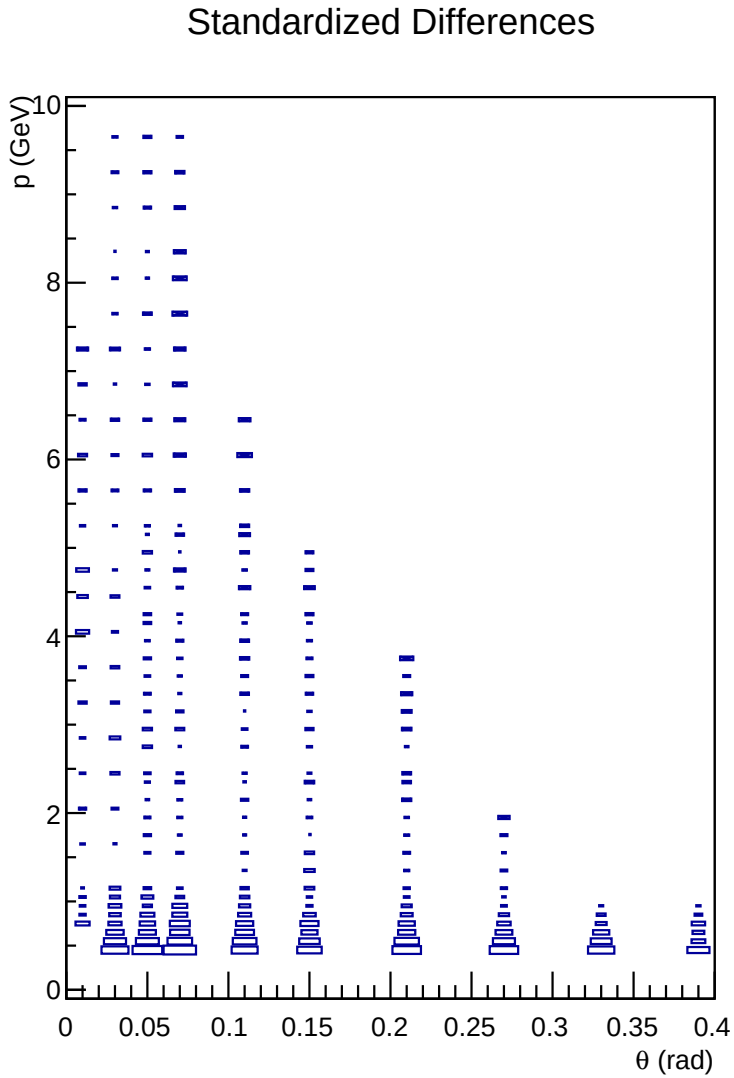
NA61
Uncertainty

As with NA49, error in the simulation is much smaller than in NA61.

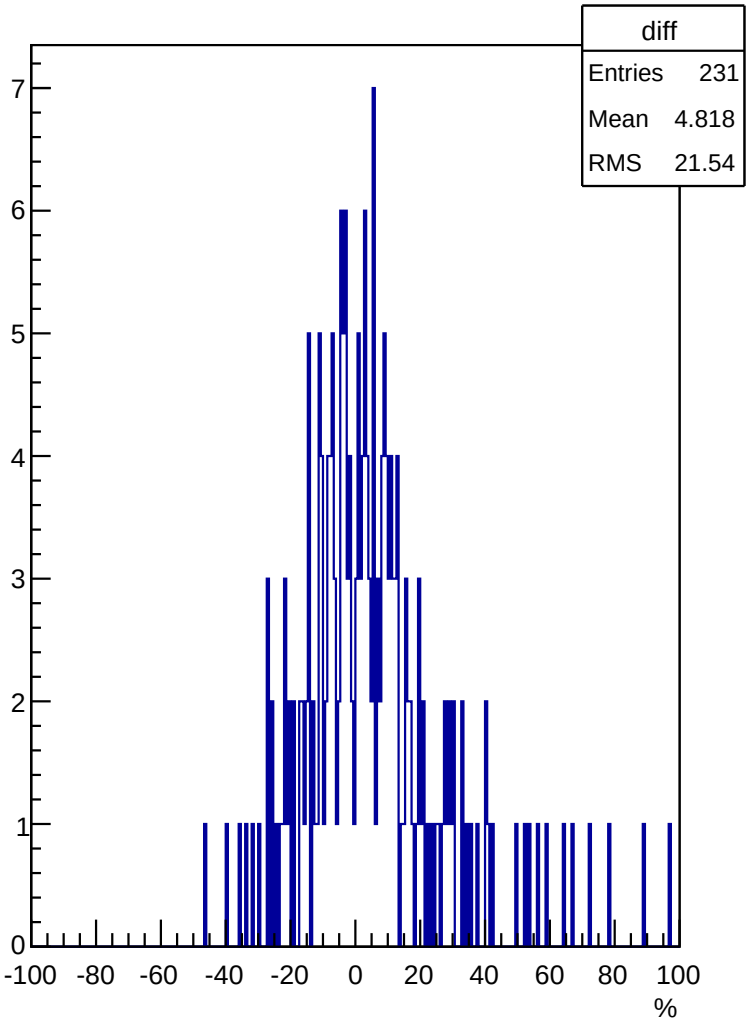
Particle	MC mean error (%)	NA49 mean error (%)
π^+	0.5	8.8
π^-	0.8	7.8

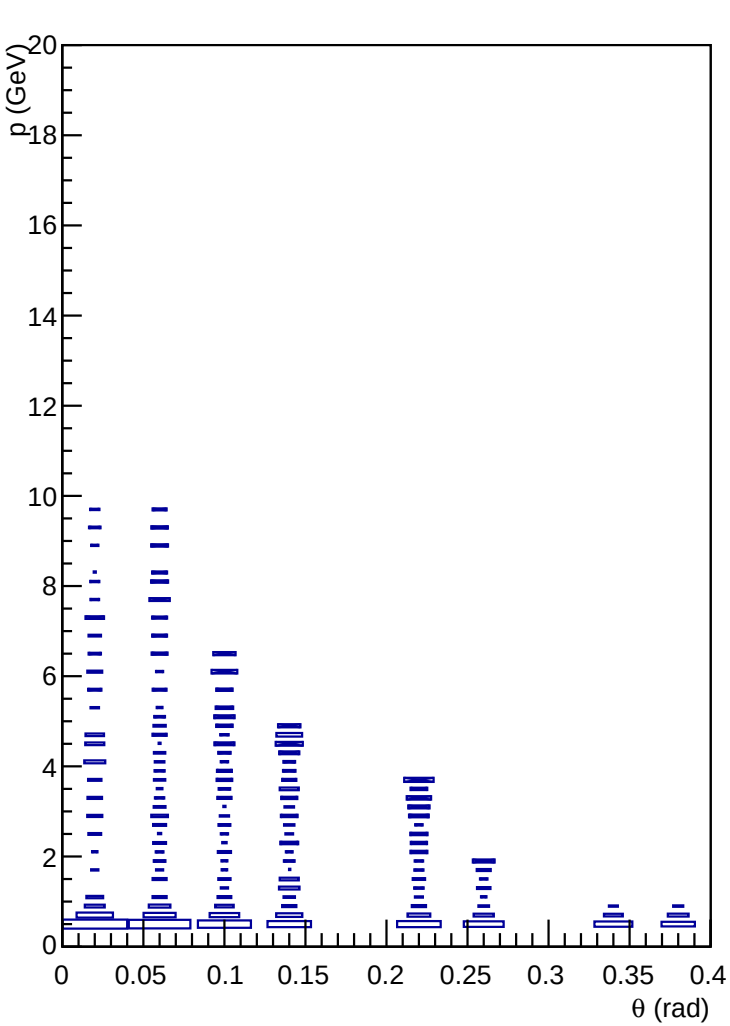
NA61 π^+ Standardized differences



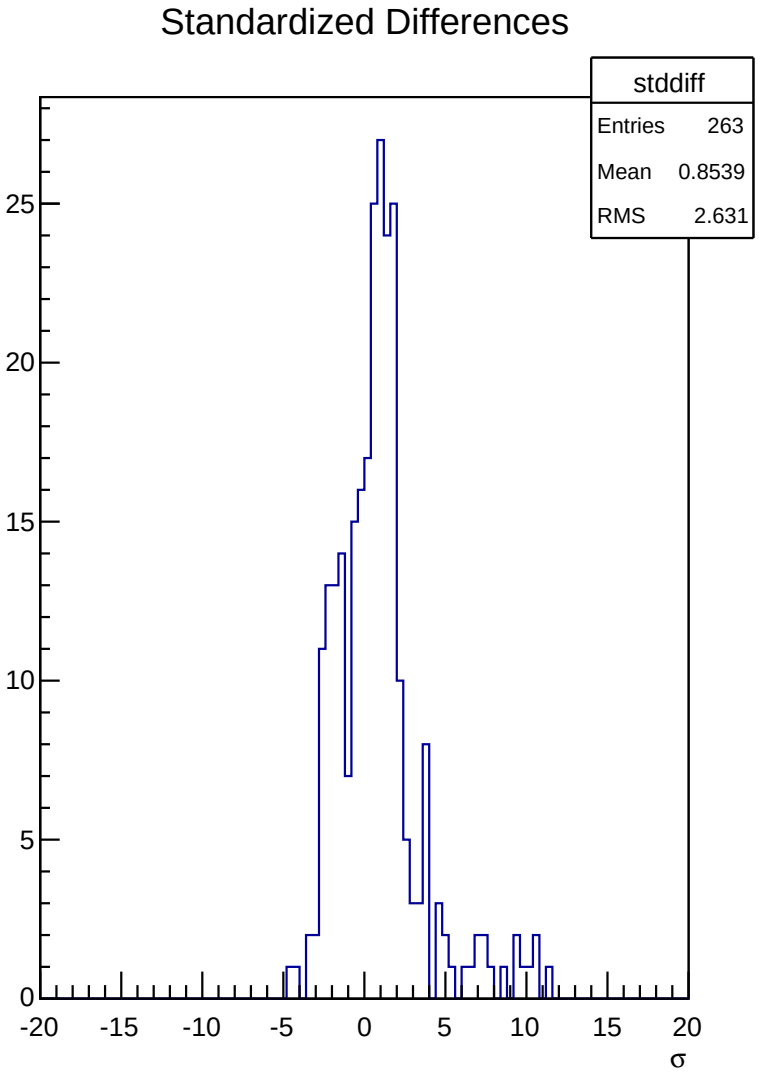


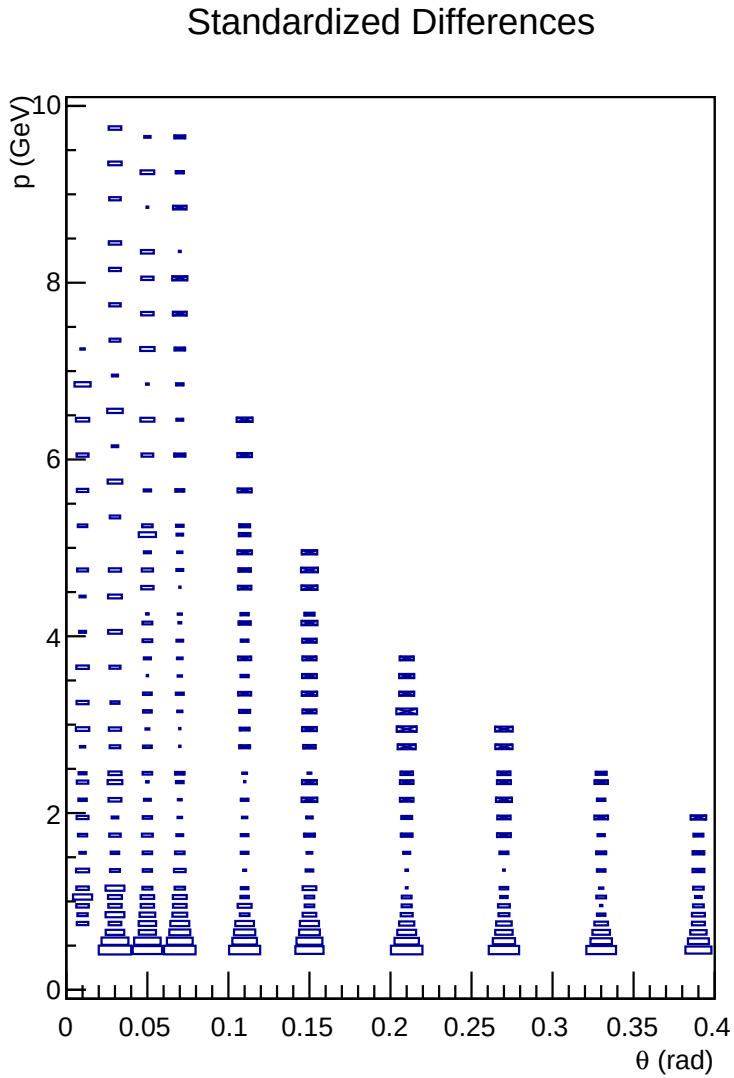
NA61 π^+ Relative differences



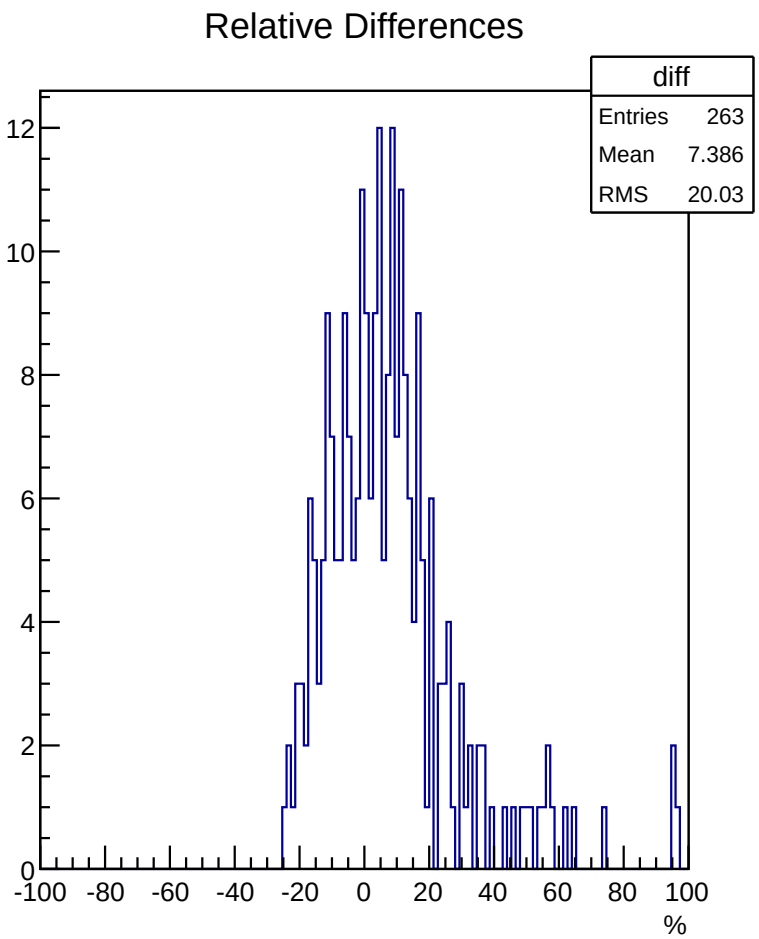


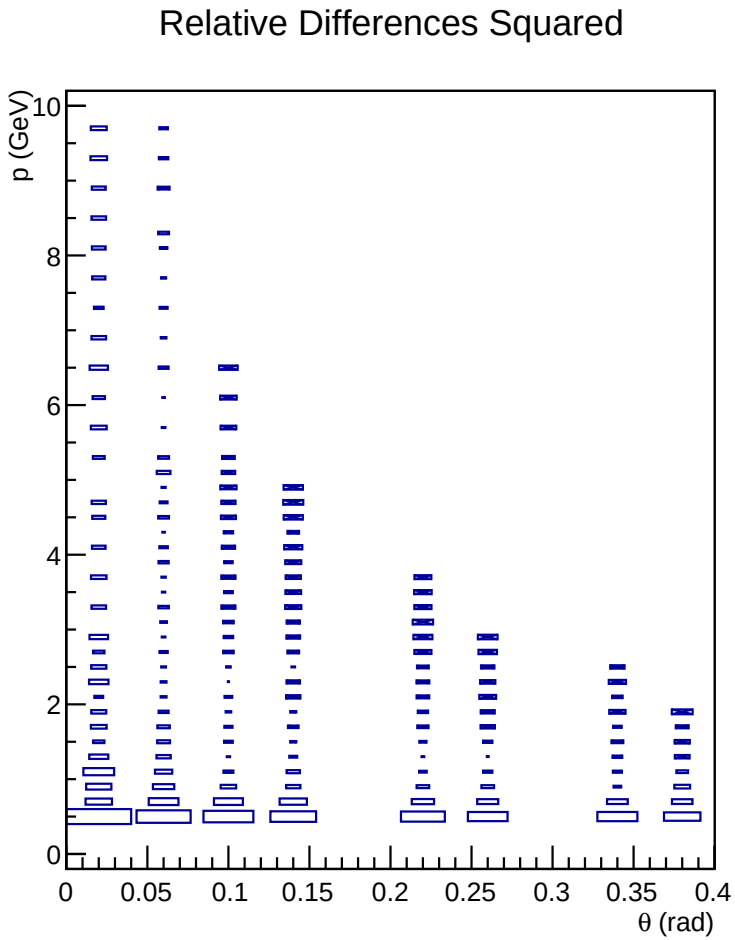
NA61 π^- Standardized differences





NA61 π^- Relative differences





Next steps

- Weighting by neutrino flux in NDOS
- Study Kaon production with NA61 setup
- Simulate beam at 120 GeV momentum and compare with the interpolation done by NA49 and NA61.